



US009455596B2

(12) **United States Patent**
Gonzalez Valdez et al.

(10) **Patent No.:** **US 9,455,596 B2**
(45) **Date of Patent:** **Sep. 27, 2016**

(54) **SYSTEM AND METHOD FOR REDUCING INTERFERENCE BETWEEN WIRELESS CHARGING AND AMPLITUDE MODULATION RECEPTION**

(2013.01); **H02J 7/042** (2013.01); **H02J 17/00** (2013.01); **H04B 5/0037** (2013.01); **H04B 5/0075** (2013.01); **H02J 2007/005** (2013.01)

(58) **Field of Classification Search**

CPC **H02J 7/025**; **H04B 5/0037**; **H04B 5/0031**
USPC **320/108**; **455/573**, **41.1**
See application file for complete search history.

(71) Applicant: **Ford Global Technologies, LLC**,
Dearborn, MI (US)

(72) Inventors: **Luis David Gonzalez Valdez**, Berkley, MI (US); **John Robert Van Wiemeersch**, Novi, MI (US); **Michael Hrecznyj**, Dearborn, MI (US)

(56)

References Cited

U.S. PATENT DOCUMENTS

3,938,018	A	2/1976	Dahl	
4,009,829	A *	3/1977	Sickles	B05B 5/043 118/629
5,952,814	A	9/1999	Van Lerberghe	
6,075,340	A	6/2000	Koenck	

(Continued)

OTHER PUBLICATIONS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/803,911**

(22) Filed: **Jul. 20, 2015**

(65) **Prior Publication Data**

US 2015/0326062 A1 Nov. 12, 2015

Related U.S. Application Data

(63) Continuation-in-part of application No. 13/652,983, filed on Oct. 16, 2012, now Pat. No. 9,124,124.

(51) **Int. Cl.**

H02J 7/00	(2006.01)
H04B 1/38	(2015.01)
H04B 5/00	(2006.01)
H02J 7/02	(2016.01)
H02J 7/04	(2006.01)
H02J 17/00	(2006.01)

(52) **U.S. Cl.**

CPC **H02J 7/025** (2013.01); **H02J 7/0047**

Power Electronics Technology, "Wireless Power Receiver IC Complements Existing Transmitter," www.powerelectronics.com/power-electronics-systems/wireless-power-receiver-ic-complements-existing-transmitter, Jul. 2011, pp. 15-17.

(Continued)

Primary Examiner — M'Baye Diao

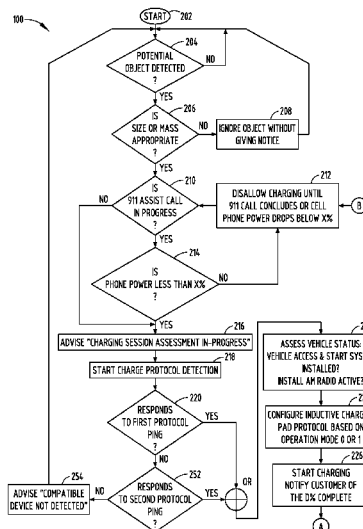
(74) *Attorney, Agent, or Firm* — Vichit Chea; Price Heneveld LLP

(57)

ABSTRACT

A method for reducing interference in an inductive charging system is provided. The method includes steps of inductively charging a chargeable device with an inductive charger, detecting the operation of a receiver in an AM band, and adjusting at least one of a frequency band employed by the charger and an amount of power provided to the chargeable device by the charger based on the operation of the receiver in the AM band.

20 Claims, 8 Drawing Sheets



(56)

References Cited**U.S. PATENT DOCUMENTS**

6,419,379	B1	7/2002	Hulse	
7,434,953	B2	10/2008	Newton et al.	
7,518,337	B2	4/2009	Beart et al.	
7,633,263	B2	12/2009	Toya	
7,772,802	B2	8/2010	Manico et al.	
7,808,205	B2	10/2010	Rao et al.	
7,889,498	B2	2/2011	Diebel et al.	
7,932,638	B2	4/2011	Randall	
7,952,322	B2	5/2011	Partovi et al.	
8,102,147	B2	1/2012	Jung	
8,103,266	B2	1/2012	Fok et al.	
8,120,311	B2	2/2012	Baarmaan et al.	
8,169,185	B2	5/2012	Partovi et al.	
8,242,741	B2	8/2012	Phelps, III	
8,373,310	B2	2/2013	Baarmaan et al.	
8,410,751	B2	4/2013	Terao et al.	
8,421,278	B2	4/2013	Yamamoto et al.	
8,645,481	B2	2/2014	Eaton	
8,805,456	B1 *	8/2014	Hardy	H02J 7/025 455/41.1
8,903,456	B2	12/2014	Chu et al.	
2003/0019931	A1	1/2003	Tsikos et al.	
2005/0127867	A1	6/2005	Calhoon et al.	
2005/0131486	A1	6/2005	Boveja et al.	
2007/0293277	A1	12/2007	Bury	
2009/0051312	A1	2/2009	Simon et al.	
2009/0146608	A1	6/2009	Lee	
2009/0197551	A1 *	8/2009	Paraskake	H04B 1/086 455/179.1
2010/0114241	A1	5/2010	Donofrio et al.	
2010/0181961	A1	7/2010	Novak et al.	
2010/0207575	A1	8/2010	Pijnenburg et al.	
2010/0253281	A1	10/2010	Li	

2010/0289448	A1	11/2010	Jung et al.
2011/0018679	A1	1/2011	Davis et al.
2011/0050164	A1	3/2011	Partovi et al.
2011/0291613	A1	12/2011	Rosik et al.
2012/0104997	A1	5/2012	Carobolante
2012/0117730	A1	5/2012	Lemire et al.
2012/0206098	A1	8/2012	Kim
2012/0235636	A1	9/2012	Partovi
2012/0299538	A1	11/2012	Arai et al.
2013/0020988	A1	1/2013	Kim et al.
2013/0049662	A1	2/2013	Keong et al.
2013/0076308	A1	3/2013	Niskala et al.
2013/0093390	A1	4/2013	Partovi
2013/0096651	A1	4/2013	Ozawa et al.
2013/0113421	A1	5/2013	Han et al.
2013/0147426	A1	6/2013	Misono
2013/0257363	A1	10/2013	Lota et al.
2013/0300204	A1	11/2013	Partovi
2014/0125277	A1	5/2014	Van Wiemeersch et al.
2014/0129054	A1	5/2014	Huntzicker et al.
2014/0176057	A1	6/2014	Van Wiemeersch
2014/0191568	A1	7/2014	Partovi
2014/0203770	A1	7/2014	Salter et al.
2014/0217965	A1	8/2014	Van Wiemeersch et al.
2014/0239891	A1	8/2014	Martin et al.

OTHER PUBLICATIONS

Texas Instruments Incorporated, "Qi Compliant Wireless Power Transmitter Manager," www.ti.com, document bq500210, Jun. 2011, Revised Aug. 2011, 25 pages.

Ngo, Dong, "CES: Universal Wireless Charging Electro-Hub to Demo at CES 2011," www.cnet.com/8301-32254_1-20024327-283.html, Dec. 1, 2010, 7 pages.

* cited by examiner

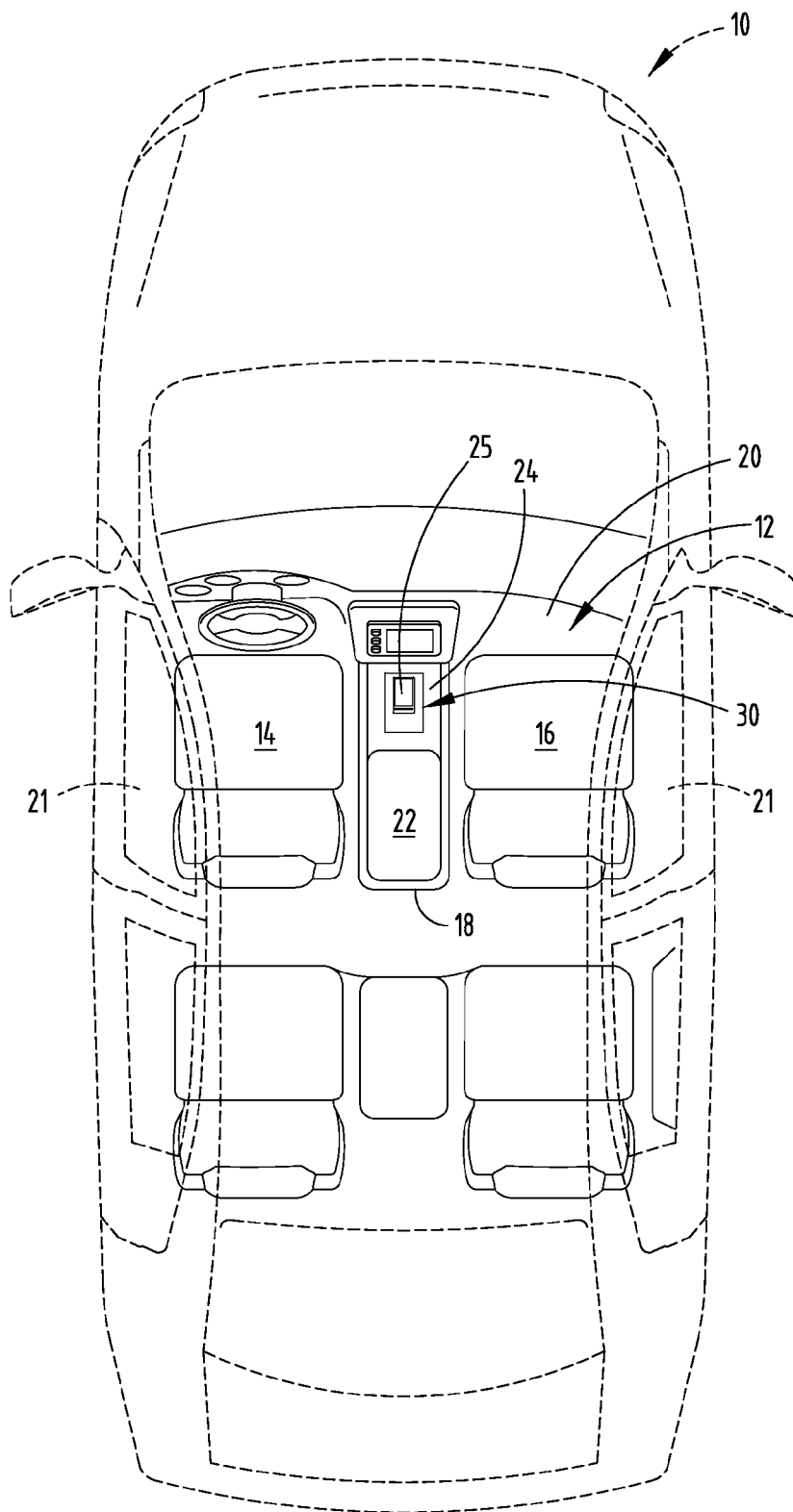


FIG. 1

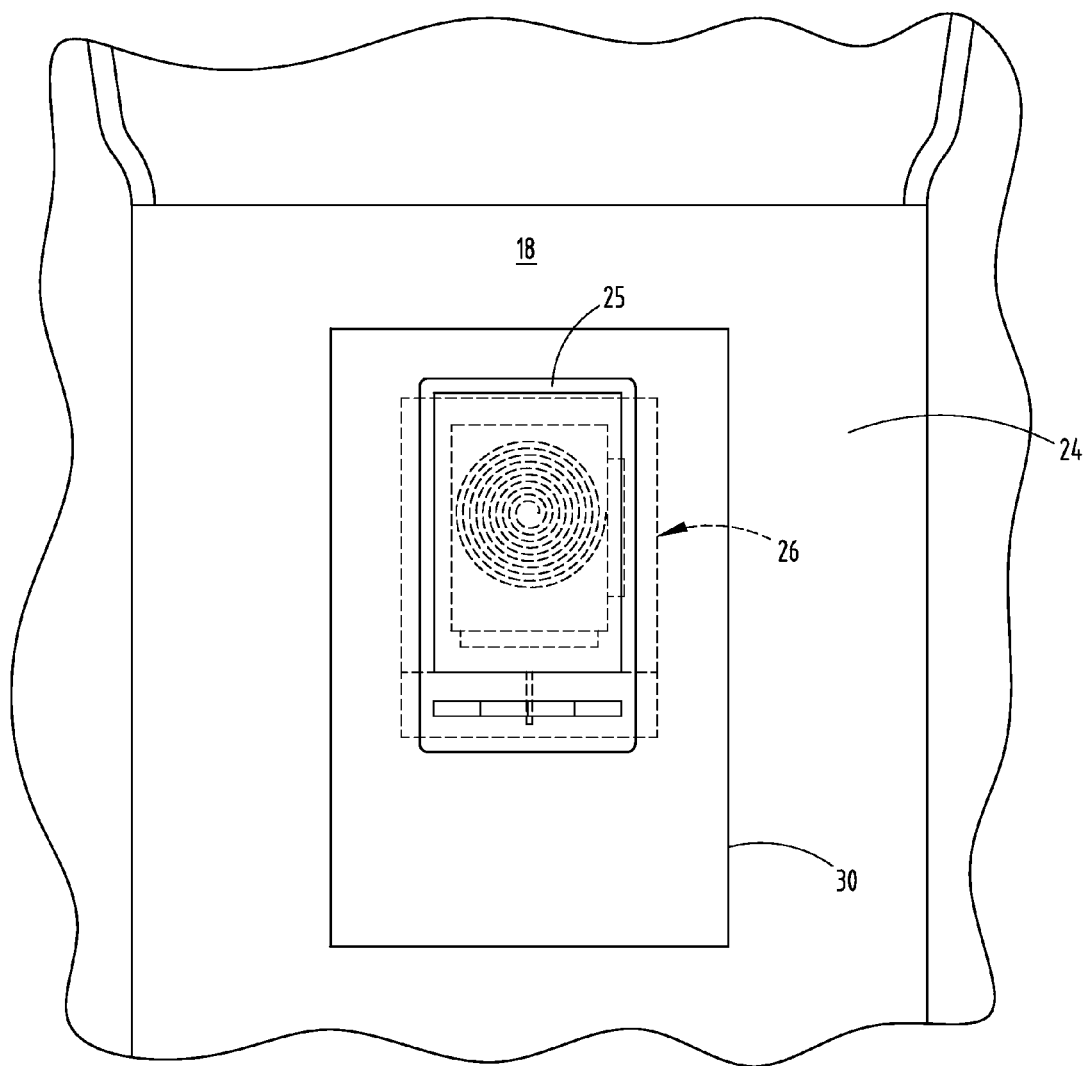


FIG. 2

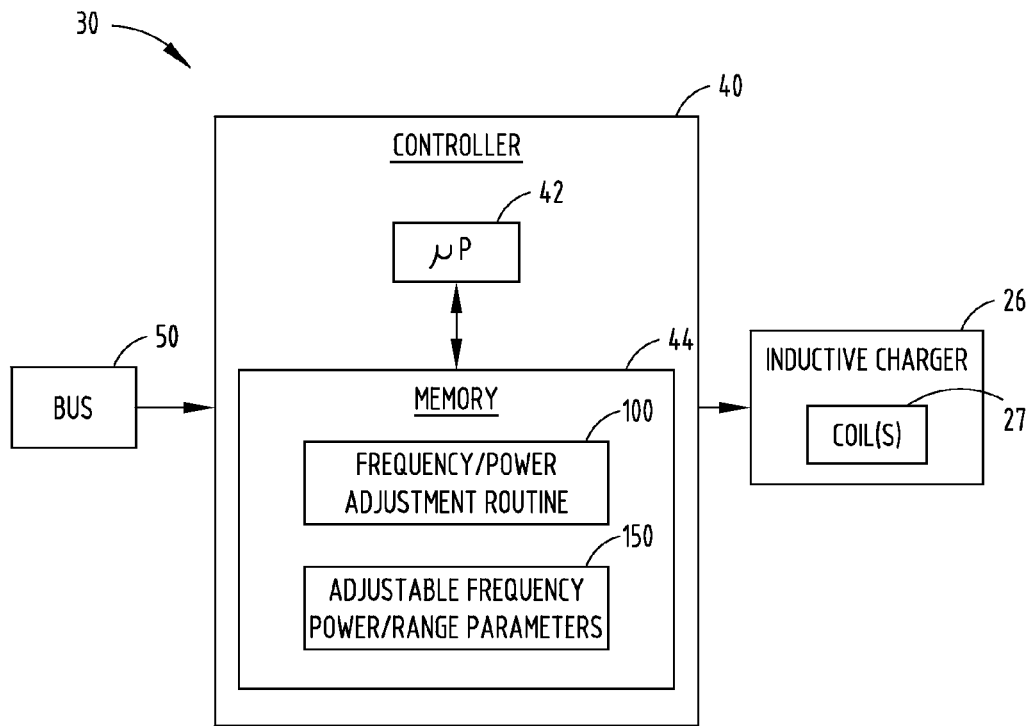


FIG. 3

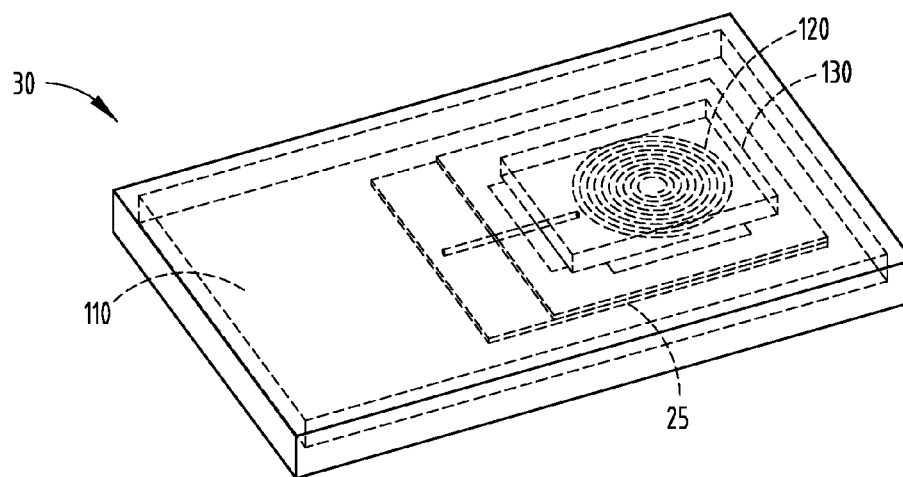


FIG. 4

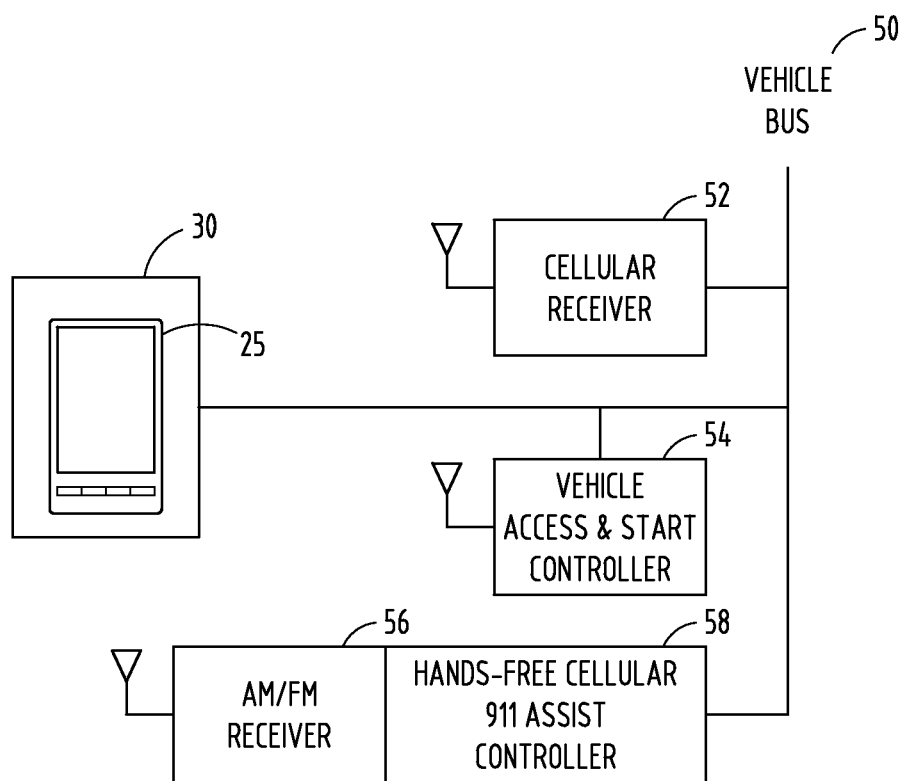
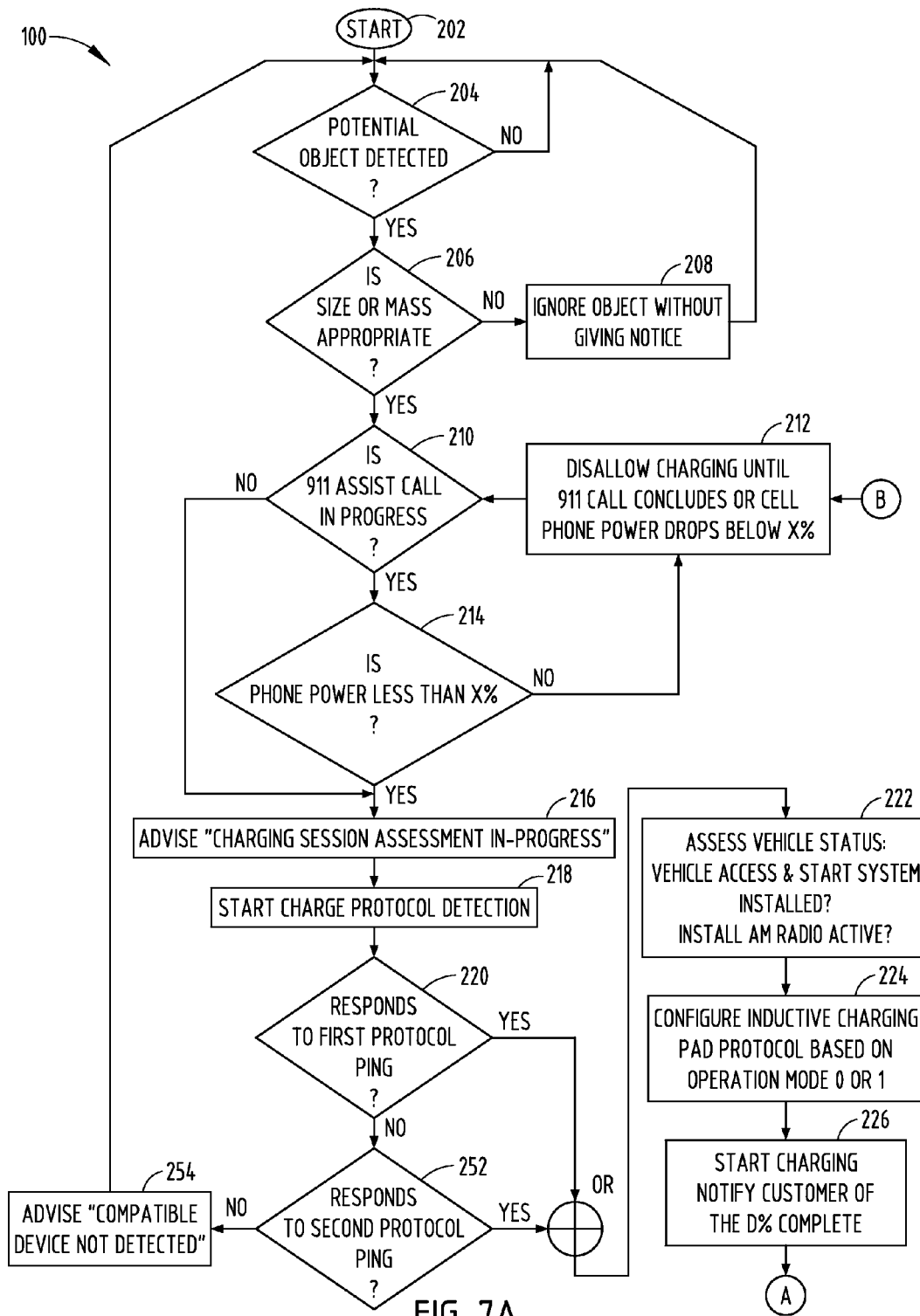


FIG. 5

VEHICLE OPERATION MODE		PROTOCOL		
		PROTOCOL 1	PROTOCOL 2	PROTOCOL 3
0	NO FACTORY EQUIPPED VEHICLE ACCESS & START SYSTEM	FULL LF BAND	FULL LF BAND	FULL LF BAND
1	VEHICLE OFF, AM/FM BAND OFF, NO VEHICLE ACCESS & START SYSTEM ACTIVATED	FULL LF BAND	FULL LF BAND	FULL LF BAND
2	AM ACTIVATE AT TUNER FREQUENCIES ≥ P kHz NO VEHICLE ACCESS & START SYSTEM ACTIVATED	FULL LF BAND	FULL LF BAND	SET INDUCTIVE CHARGING PAD (TUNER /4)
3	AM ACTIVE AT TUNER FREQUENCIES < P kHz NO VEHICLE ACCESS & START SYSTEM ACTIVATED	SET INDUCTIVE CHARGING PAD (TUNER FREQ/4)	SET INDUCTIVE CHARGING PAD (TUNER FREQ/4)	SET INDUCTIVE CHARGING PAD (TUNER FREQ /2)
4	ALTERNATIVE ACTIVE VEHICLE ACCESS & START SYSTEM START/RUN QUERY (START, ENTRY, OR KEY STATUS CHECK)	EXCLUDE A - B kHz BAND FOR LF CHARGING	EXCLUDE A - B kHz BAND FOR LF CHARGING	FULL LF BAND
5	VEHICLE ACCESS & START SYSTEM KEY FOB LOCATION TRIANGULATED	EXCLUDE A - B kHz BAND FOR LF CHARGING	EXCLUDE A - B kHz BAND FOR LF CHARGING	FULL LF BAND
6	PHONE MISS-ALIGNED ON INDUCTIVE CHARGING PAD (OPTION TO REDUCE POWER)	HOLD LF BAND SETTING, REDUCED POWER Z%	HOLD LF BAND SETTING, REDUCED POWER Z%	HOLD LF BAND SETTING, REDUCED POWER Z%
7	1st ATTEMPT ACTIVE VEHICLE ACCESS & START SYSTEM START/RUN QUERY (START, ENTRY, OR KEY STATUS CHECKS QUERY)	HOLD LF BAND SETTING, REDUCED POWER C% FOR T SECONDS	HOLD LF BAND SETTING, REDUCED POWER C% FOR T SECONDS	FULL LF BAND
8	SECOND ATTEMPT OF VEHICLE ACCESS & START SYSTEM START/RUN QUERY IF KEY NOT FOUND (START, ENTRY, OR KEY STATUS CHECKS)	SUSPEND CHARGING FOR T SECOND	SUSPEND CHARGING FOR T SECOND	FULL LF BAND
9	911 ASSIST CALL TO BE INITIATED	SUSPEND CHARGING IF PHONE SOC > X%		
10	911 ASSIST CALL IN-PROGRESS	SUSPEND CHARGING FOR DURATION OF 911 CALL UNLESS PHONE SOC DROPS BELOW X% THEN RE-INITIATE CHARGING		

FIG. 6



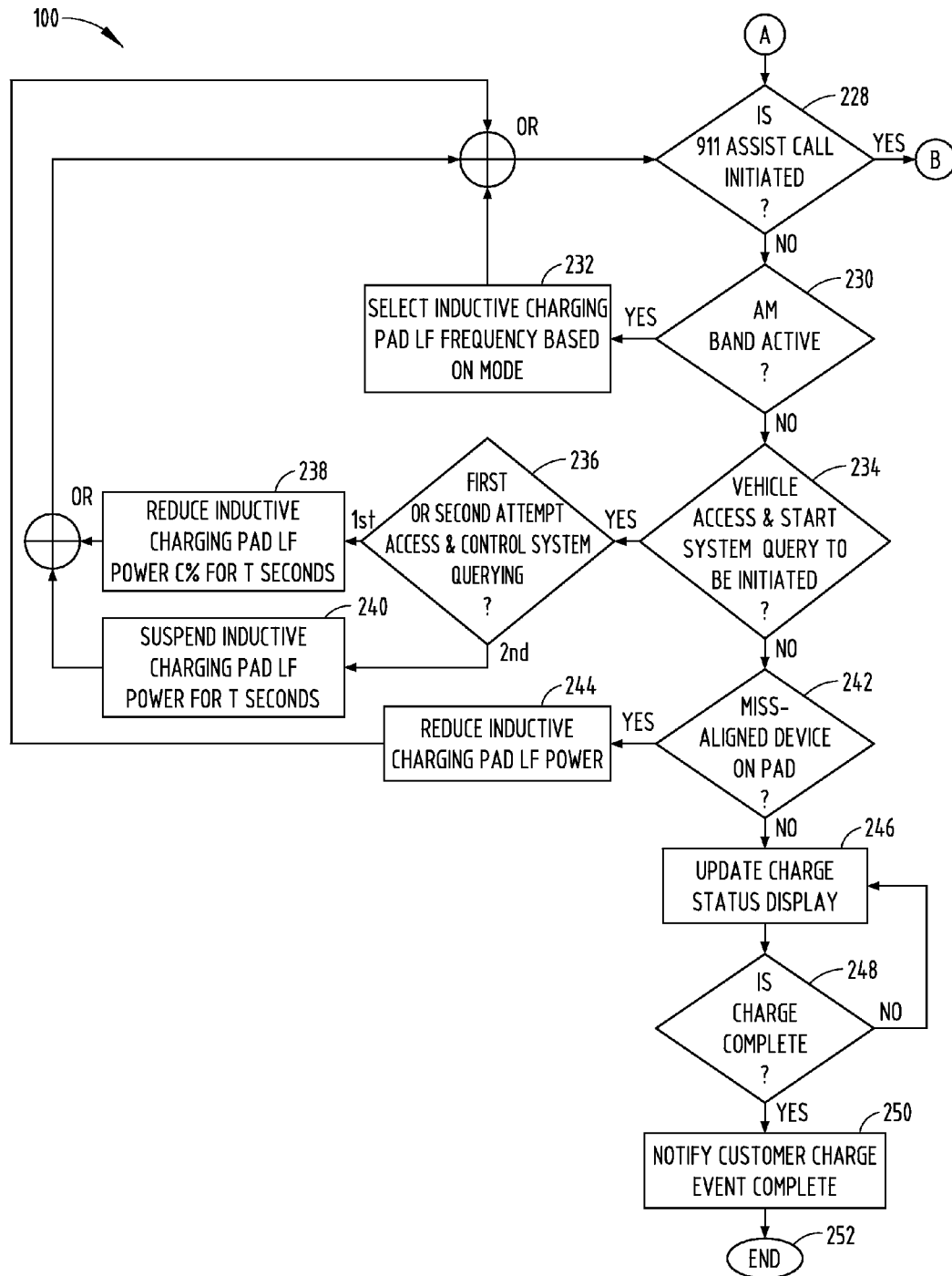


FIG. 7B

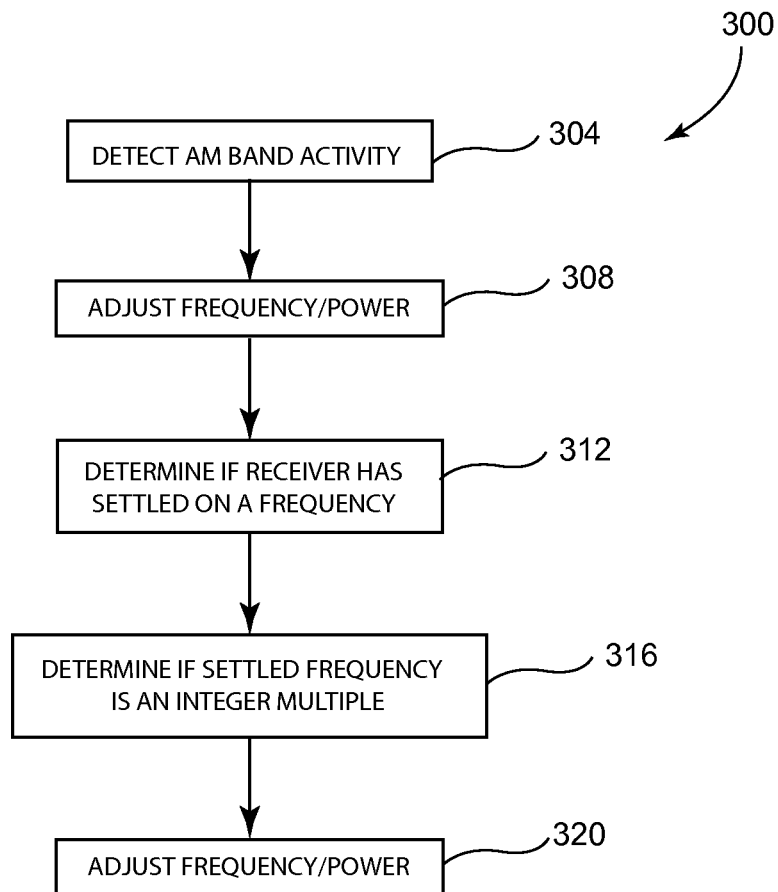


FIG. 8

1

SYSTEM AND METHOD FOR REDUCING INTERFERENCE BETWEEN WIRELESS CHARGING AND AMPLITUDE MODULATION RECEPTION

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. patent application Ser. No. 13/652,983, filed on Oct. 16, 2012, entitled "SYSTEM AND METHOD FOR REDUCING INTERFERENCE DURING WIRELESS CHARGING", now U.S. Pat. No. 9,124,124. The aforementioned related application is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention generally relates to wireless charging systems, and more particularly, relates to reducing interference during wireless charging of portable devices in a vehicle.

BACKGROUND OF THE INVENTION

Portable battery operated electronic devices, such as cell phones, employ rechargeable batteries that must be recharged when battery charge is consumed. Typically, electric-powered or electronic devices are physically connected to an electrical charger via a wire connection. More recently, wireless charging devices such as inductive chargers are available to charge the battery without any physical wire connection between the electronic device and the charging device. Wireless chargers generate an electromagnetic field through the use of electromagnetic transducers to transfer the electric energy from the charging device to a receiver on a battery or device having a battery being charged. Inductive chargers generate a magnetic field through the use of inductive coils to transfer the electric energy from the charging device to a receiver on a battery or device having a battery being charged. Inductive chargers have been proposed for use on vehicles in various locations having a portable battery or a battery operated device within the cockpit of the vehicle, typically near the driver and other passengers, for the sake of convenience to allow easy access to the devices. However, the electromagnetic field may potentially emit energy producing frequency interference with other systems in the vehicle or brought to the vehicle. Magnetic resonance chargers may also cause interference, but the interference may be to a lesser degree. It is therefore desirable to provide a wireless charger within a vehicle in a manner that minimizes the introduction of frequency interference with other systems used in the vehicle.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, a method for reducing interference in an inductive charging system is provided. The method includes steps of inductively charging a chargeable device with an inductive charger, detecting the operation of a receiver in an AM band, and adjusting at least one of a frequency band employed by the charger and an amount of power provided to the chargeable device by the charger based on the operation of the receiver in the AM band.

According to another aspect of the present invention, a charging system for reducing interference during inductive

2

charging of a chargeable device is provided. The charging system includes an inductively powered charger and a controller configured to detect the selection of an AM tuning mode of a receiver in proximity to the charger. The charging system adjusts the frequency band employed by the charger if the receiver is tuned to a frequency within the predetermined portion of the AM band.

According to another aspect of the present invention, an in-vehicle system for reducing interference during inductive charging of a chargeable device is provided. The in-vehicle system includes a charger region provided in a vehicle, an inductively powered charger and a controller in communication with the inductive charger. The controller detects operation of a vehicle receiver in a scan mode of an AM frequency band in proximity to the charger and adjusts a frequency band employed by the charger.

These and other aspects, objects, and features of the present invention will be understood and appreciated by those skilled in the art upon studying the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a perspective view of a cockpit of a vehicle employing a wireless charger at a potential charging region, according to one embodiment;

FIG. 2 is an enlarged top view of a portion of the vehicle cockpit further illustrating the charging region located on a center console of a vehicle with a portable chargeable device in proximity to the charger;

FIG. 3 is a block diagram of an inductive charging system, according to one embodiment;

FIG. 4 is a perspective view of an inductive charging system, according to one embodiment;

FIG. 5 is a schematic block diagram of a wireless charging system configured to reduce interference between the inductive charging system and other systems in a vehicle, according to one embodiment;

FIG. 6 is a table illustrating operations implemented by the wireless charging system based upon inductive charging protocol and operation mode, according to one embodiment;

FIGS. 7A and 7B are a flow diagram illustrating the frequency/power adjustments routine for reducing interference in an inductive charging system 1, according to one embodiment; and

FIG. 8 is a flow chart illustrating an operation implemented by the wireless charging system based on use of a radio in an AM band proximate the wireless charging system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to a detailed design; some schematics may be exaggerated or minimized to show function overview. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention.

Referring to FIGS. 1 and 2, the interior of an automotive vehicle 10 is generally illustrated having a passenger com-

3

partment 12 employing a wireless inductive charging system 30, according to one embodiment of the present disclosure. The vehicle 10 generally includes a seating arrangement including a front driver seat 14 and front passenger seat 16, each adapted to seat a person as an occupant in the passenger compartment 12 of the vehicle 10. The vehicle 10 also includes a center console 18 with a storage compartment 22 disposed between the front seats 14 and 16 and side door armrests 21. The center console 18, dashboard 20, and armrests 21, as well as other vehicle assemblies, may be equipped with various device holders, such as trays and storage compartments that may receive one or more devices for wireless charging. The vehicle 10 may further include rear seating and wireless charging trays and storage compartments configured for wireless inductive charging located in the rear seating area.

FIG. 2 illustrates an enlarged view of a portion of the interior of the automotive vehicle 10 containing an inductive charging system 30. In the embodiment shown, a charging region 24 may be located on the center console 18 of the vehicle 10 and a portable chargeable device 25 may be placed on the surface of the charging system 30. The vehicle 10 may be equipped with one or more wireless charging systems 30 for wirelessly charging one or more devices, including one or more rechargeable batteries providing electrical power within an electronic device. In one embodiment, one or more wireless charging systems 30 may be provided in one or more storage trays or dedicated trays provided in center console 18. The wireless charging system 30 includes a wireless inductive charger 26. Inductive chargers typically include one or more inductive coils for generating electric signals in the form of an electromagnetic field (EMF) typically at low frequencies within a charging region 24. In the embodiment shown, the charging region 24 may be defined by a tray or a storage compartment having a bottom wall and side walls for receiving a device, such that the device, when located within the charging region 24, may be charged via the electromagnetic field through inductive coupling. According to another embodiment, the wireless charging system 30 may use a charging region 24 provided on one or more pads or trays provided in the vehicle dashboard 20. According to a further embodiment, the wireless charging system 30 may use a charging region 24, provided with an inductive charger 26, located in a tray within the armrest 21 extending from a vehicle door. In each of these embodiments, the wireless charging system 30 has a charging region 24 adapted to receive one or more devices, such as rechargeable batteries or electric powered or electronic devices 25 employing rechargeable batteries, that may be charged via an electric signal on the charging region and may be accessible to the driver or other passengers within the cockpit 12 of vehicle 10. Examples of electronic devices 25 that may be charged by the charging system 30 include cell phones, computers, radios, lighting devices, and music and video players.

Referring to FIG. 3, the wireless charging system 30 is further illustrated having control circuitry, shown in one embodiment as a controller 40, including a microprocessor 42 and memory 44. The controller 40 may include other or additional analog and/or digital circuitry. Stored within memory 44 may be a frequency/power adjustment routine 100 and adjustable frequency range and power charging parameters 150. The controller 40 may receive, as inputs: 1) a signal indicative of the current charger state 30 (e.g., on or off); and 2) information via a network bus 50 relating to at least one of a detected interfering operation mode of vehicle systems in proximity to wireless charging system 30. The

4

vehicle operation mode information may include frequency band of a vehicle system (e.g., amplitude modulation/frequency modulation (AM/FM) scanning or tuning of a radio), status information for a vehicle system such as active/inactive or in progress/to be initiated, and positional information of a system in the vehicle relative to controller 40. Detection of such modes of operation may indicate that a device operating in such a mode would create or accept a frequency that would cause potential interference with vehicle systems. The interference can be in the form of radiated emissions and/or conducted emissions. Interference may also be generated by magnetic resonance chargers since some manufacturers have solutions that operate in the kilohertz range and may have fundamentals or harmonics which may cause interference (e.g., via harmonics or fundamentals in the AM frequency band). Such interference between vehicle devices and the charger 30 may cause failure of the vehicle device, or the charger 30, to operate ineffectively, as well as the potential for a device under charge to overheat by being overexposed to a particular frequency of the charger 30. Following detection of a potential interfering mode of operation, the controller 40 may process this input information with respect to the protective frequency/power adjustment routine 100 and generate an output to the inductive charger 26 having inductive coil(s) 27 so as to at least reduce or prohibit the electrical charging signal to be generated by the charger 26 and/or adjust the frequency within the charging region in order to avoid potential frequency interference with other vehicle modules.

FIG. 4 illustrates a possible implementation of a wireless inductive charging system 30, according to some embodiments of the present invention. In FIG. 4, a transmitter section 110 may be housed in the charging system 30. The transmitter section 110 may contain one or more transmitter coils (not shown) which may be coupled to a connector that is plugged into a standard external power source. A receiver 130 may be housed in a chargeable electronic device 25. The transmitter section 110 may provide power to the receiver 130 such that the receiver 130 provides power to a rechargeable battery and the transmitter section 110 may receive additional control information from the receiver 130 to adapt to a particular power transfer based on the control information.

The vehicle charging system 30 may include one or more wireless chargers for generating electric charging signals in the charger region 24 to charge the electronic device 25 containing a rechargeable battery. The wireless charger may include the inductive charger 26 generating an electromagnetic field. The inductive charger may include one or more inductive coils 27 located below or on the bottom surface of the charger region 24, such as a pad for generating an electromagnetic field in the charger region 24. The electromagnetic field passes from inductive coils 27 into the charger region 24 and is intended to wirelessly couple to one or more inductive receiver coils 120 provided in the portable electronic device 25, so as to transfer electrical energy thereto for purposes of charging one or more rechargeable batteries. As a result, an electromagnetic field is present within the charger region 24.

FIG. 5 shows a schematic illustration depicting one embodiment of an adaptable wireless communication system including a network connection between the wireless charging system 30 and a vehicle access, and a start system, including a plurality of additional features integrated in the vehicle. The charging system 30 may interface with a plurality of networks via the vehicle network bus 50, such as a privately accessible network such as WAN/LAN, publicly

5

accessible networks, such as the Internet, in-vehicle networks, such as Controller Area Networks (CAN) and Assembly Line Data Link (ALDL). When the charging system 30 is connected to an in-vehicle data bus 50, the controller 40 in the wireless system 30 may accept incoming operation mode information from other vehicle devices connected to the in-vehicle data network, such as frequency band information, status information, such as active/inactive and indication of progress/initialization, and positional information of a device relative to system 30. In addition, when connected to an in-vehicle data network, the controller 40 may monitor the in-coming operation mode information from other vehicle electronic devices and systems connected to the network as well as operating frequency of the system 30. Depending on the operation mode detected by the controller 40, the controller 40 may issue commands modifying the charging frequency of the charger 26 and/or the amount of power used by the charger 26 to charge the rechargeable battery or batteries of the portable device 25 by adjusting the electrical charging signal generated by the charger 26.

As shown in one embodiment in FIG. 5, the in-vehicle data bus 50 allows for communication between the wireless charging system 30 and various components integrated within the vehicle 10, such as a cellular receiver 52, a vehicle access and start controller 54, an AM/FM receiver 56, and a hands-free cellular 911 Assist controller 58. The controller 40 within the wireless charging system 30 may be instructed to charge wireless devices 25 at a particular frequency band, depending on the type of inductive charging protocol that a device 25 responds to. Some examples of inductive charging protocols that a charging system 30 may be equipped with are: Qi Wireless Power Consortium (WPC), which may operate on a low frequency band of 90 kHz-205 kHz, Powermat Generation 2, which may also operate on a low frequency band of 90 kHz-205 kHz, and Powermat Generation 1, which may operate on a low frequency band of 270 kHz-370 kHz. Similarly, Qi magnetic resonance solutions operate in approximately the same frequency band as a Qi magnetic induction (i.e., inductive) charging solution. Other inductive charging protocols and other operating frequencies may be employed. In a specific embodiment, the charger 26 may operate at a charging frequency of about 110 kHz.

A cellular receiver 52 may be contained within a cellular device that is equipped inside the vehicle 10. The receiver 52 may also allow the user to receive phone calls from any remote phone and transmit phone calls from an integrated vehicle 10 by operating at a frequency of 850 MHz to 1900 MHz, depending on the type of mobile standard (such as GSM or CDMA) on which the cellular device operates. The cellular receiver 52 may broadcast a message to the charging system 30 over the vehicle bus 50 indicating that the vehicle cellular device is receiving and transmitting data and may be susceptible to a potential interfering frequency from the operating band of the inductive charger system 30. Alternatively, the operating frequency of the cellular receiver 52 may be measured by a vehicle access and start controller 54 and the vehicle access and start controller 54 may broadcast a message over the vehicle bus 50 to the charging system 30, indicating that the cellular device is operating at a frequency that may be susceptible to potential interference from the operating frequency of inductive charger 30.

The AM/FM receiver 56 may be contained within a vehicle radio (not shown) that is equipped inside the vehicle 10. The AM/FM receiver 56 may support North American FM bands operating at a frequency of 88 MHz to 108 MHz

6

and North American AM bands operating at a frequency of 520 kHz to 1610 kHz, as well as other worldwide audio bands, such as long wave and NOAA weather band. The AM/FM receiver 56 may broadcast a message to the charging system 30 over the vehicle bus 50 indicating the vehicle radio is tuned to a station with a frequency band that would potentially see interference from the operating frequency of the charging system 30. Alternatively, the operating frequency of the AM/FM receiver 56 may be measured by a vehicle access and start controller 54. If the vehicle access and start controller 54 determines the operating frequency reaches a certain threshold, it will broadcast a message over the vehicle bus 50 to the charging system 30 indicating the receiver 56 is operating at a frequency that potentially may see interference from the operating frequency of the inductive charger 30.

The 911 Assist controller 58 contained within a 911 Hands-Free Cellular Assist System (not shown) may be equipped inside the vehicle 10. The 911 Hands-Free Cellular Assist System may synchronize with a driver's cellular device allowing for hands-free cellular phone capabilities while driving and also connecting the driver directly to a local 911 operator in the event an accident is detected within the vehicle (for example, vehicle airbags deploy or emergency fuel pump shutoff is activated). This feature may deliver a voice message to operators indicating the vehicle has been in an accident. If an accident occurs while the driver is using the hands-free phone capabilities, the 911 Assist System would automatically end that call and dial 911. If an occupant of the vehicle is unable to communicate with the 911 operator, a message sent by the Assist System tells the 911 operator that an accident has occurred and location information provided by the mobile phone carrier is given to the operator. If a 911 Assist Call is either in progress or about to be initiated, the 911 Assist controller 58 may broadcast a message to the inductive charging system 30 over the vehicle bus 50 indicating the charging of a mobile device 25 is to be suspended in order to reduce the probability that the inductive charger 30 will interfere with the 911 Assist Call. An example of a 911 Hands-Free Cellular Assist System is Ford Motor Company's SYNC® 911 Assist feature, which may be equipped onto Ford's vehicles.

Once the controller 40 receives from the network bus 50 status messages from a vehicle module, such as the cellular receiver 52, vehicle access and start controller 54, AM/FM receiver 56, and 911 Assist controller 58, the controller 40 will process the input information with respect to a routine 100 stored in memory 44 executed by control circuitry which in turn will adjust the electrical charging signal frequency and/or amplitude to be generated by the charger 26 in order to avoid potential inference with other vehicle modules.

The table shown in FIG. 6 illustrates one embodiment of actions that may be affected by the frequency/power adjustment routine 100 of the wireless charging system 30, depending on the type of inductive charging protocol device 25 responsible to the protocol and the mode of operation of vehicle modules detected by the charging system 30. FIG. 7 shows a general flow chart illustrating the various steps of the adjustment routine 100 that may be executed by the controller 40 based upon the mapping shown in FIG. 6.

Referring to FIG. 7, the routine 100 begins at step 202 and may determine if the wireless charger is on and proceeds to step 204. In step 204, the controller 40 determines whether a potential object has been detected on the surface of the charging system 30 and if the object detected is capable of being charged inductively by the system 30. If in step 204,

7

the controller 40 determines these conditions have been met, the controller 40 advances to step 206. Otherwise, the controller 40 returns to step 204 to determine whether a new target object has been detected on the surface of system 30 and whether the object detected can be charged inductively.

In step 206, the controller 40 determines if the object meets certain thresholds for size and/or mass. In this step, the controller 40 determines if the size and/or mass of the object detected is within a threshold criteria where it is expected that the object may be a device expecting to be charged by the charging system 30. If the object does not fall within the threshold criteria, the controller 40 advances to step 208 in which it ignores the object without giving notice to the user and returns to step 204 to determine whether a new target object has been detected on the surface of charging system 30 and whether the object detected can be charged inductively. If the object does meet the threshold criteria of step 206, the controller 40 advances to step 210. By not generating any energy until a potential receiver of a chargeable device has been detected, the system reduces the occurrence of potential broadcast radio frequency noise and mitigates the risk of interference from non-chargeable devices being left on the charging system 30.

In step 210, the controller 40 determines whether a synchronized 911 Assist Call is in progress. The controller 40 advances to step 216 if synchronized 911 Assist is not in progress. If the Assist Call is in progress, the controller 40 then proceeds to 214 to decide whether a) the power remaining in the portable device, such as cellular device 25, falls below a predetermined X % or b) the power level of the cellular device 25 cannot be read. If neither of these conditions are met, the controller 40 proceeds to step 212 in which charging becomes suspended unless the State of Charge (SOC) of the phone falls below X % and then proceeds back to step 210 in order to keep the cellular device 25 charging and active while the 911 Assist call is in progress. As also noted in Vehicle Operation Mode 10 of FIG. 6, charging is suspended irrelevant of the system 30 wireless charging protocol usage. Steps 210, 212 and 214 assist in reducing the probability of frequency interference between the 911 Assist Call and the operating frequency of the charging system 30 during charging. Additionally, steps 212 and 214 account for situations where suspension of the charge should not be activated despite the potential for frequency interference from an actively charging device 25 while 911 Assist is in progress or to be initiated. These type of situations occur when the SOC falls below a predetermined X %, such as 40%, where it would be imprudent to suspend charging below the predetermined X % level. Suspending charging below such a predetermined X % level may not give the cellular device 25 sufficient power to fully complete the 911 Assist operation or to allow for additional calls using the 911 Assist Call if the initial 911 Assist Call fails. If, in step 306, the controller 40 determines that the wireless technology standard reading can be obtained and power is not less than X %, the controller 40 advances to step 216.

In step 216, the controller 40 outputs a visual indication to the user that the "Charging Session Assessment" is in-progress. The visual indication may be disposed upon the charging region 24 and/or elsewhere in the charging system 30 or the vehicle 10. The controller 40 next advances to step 218 to initiate determination of the type of inductive charging protocol that the device 25 may respond to and with which the charging system 30 may be equipped. Each inductive charging protocol operates to generate charging power at a predetermined frequency band. For example, Qi

8

Wireless Power Consortium (WPC) and Powermat Generation 2 may operate on a low frequency band of 90 kHz-205 kHz, whereas Powermat and Powermat Generation 1 may operate on a low frequency band of 270 kHz-370 kHz.

The controller 40 next determines in step 220 whether the chargeable device 25 responds to a first protocol ping. In this step, the transmitter circuit 110 of the charging system 30 will attempt to communicate with the receiver 130 of the rechargeable device 25 by sending a digital ping (a short periodic test pulse) to the receiver 130. After transmission of the digital ping, if the receiver 130 sends an appropriate feedback signal back to transmitter 110, this indicates the receiver is a valid, first protocol compliant system and the controller 40 will proceed to step 222. If the device does not respond to a first protocol ping, the controller 40 proceeds to step 252 to determine if the device responds to a second protocol ping. For example, in step 220, the controller 40 may attempt to communicate with the device 25 via a Qi standard compliant ping. If chargeable device 25 is non-responsive to the Qi compliant ping, the controller 40 may then attempt to communicate with the device 25 via a Powermat compliant ping. If the chargeable device does not respond to either a first protocol ping or a second protocol ping, the controller 40 may indicate to the user that a "compatible device was not detected" in step 254 and proceed back to step 204 to detect whether another potential object is on or in proximity to the charging system 30. In other embodiments, there may be additional steps after step 252 testing if the chargeable device 25 responds to additional protocol pings.

In another embodiment, the charging system 30 may visually indicate to the user that the system is first protocol or second protocol compliant. For example, following satisfaction of step 220 or 252, the charging system 30 may output a visual indication upon the charging region 24 and/or charging system 30 to a user that the chargeable device is "Qi Compliant" or "Powermat Compliant." Such a visual indication may take the form of a logo or trademark representing the inductive charging protocol that the chargeable device 25 was found compliant with.

If chargeable device 25 responds to either the first protocol ping or the second protocol ping, the controller 40 then proceeds to step 222 to detect if a plurality of other electronic devices within the vehicle 10 are installed, including a vehicle access and start system and/or a vehicle radio AM/FM band. The controller 40 next, in step 224, configures the charging system 30 based upon operation modes labeled 0 or 1 if the vehicle access and start system or vehicle radio AM/FM band is detected as uninstalled or inactive. Otherwise, the controller 40 proceeds to step 228. Such detection in step 222 may be a message from a separate module in the vehicle communicating to the controller 40 of the charging system 30 the uninstalled or inactive state of the vehicle access and start system and vehicle radio. In another embodiment, it may be assumed that if the controller 40 does not receive any messages from the vehicle modules to operate in a different mode within a predetermined time, then controller 40 will communicate to the charging system 30 to charge the portable device 25 based upon operation modes 0 or 1.

Details of an example of operation modes 0 or 1 are described below with respect to FIG. 6. As shown in FIG. 6, if the vehicle operation mode communicated to the controller 40 via the vehicle bus 50 indicates no factory equipped vehicle access and start system (mode 1) or the vehicle is off, AM/FM band is off, or no vehicle access and start system is activated (mode 2), then the controller 40 will instruct the

inductive charger **26** to charge the portable device **25** on full LF band, depending on the type of protocol with which the system **30** is operating. For example, if system **30** operates on a Qi Wireless Power Consortium (WPC) protocol, the charging system **30** would be instructed to charge the portable device **25** at a low frequency band of 90 kHz-205 kHz during operation modes **0** or **1**. The operating frequency does not need to be adjusted during detection of operation modes **0** or **1** because mitigation of frequency band interference between the vehicle modules and the charging system **30** will not be an issue if the vehicle modules are uninstalled or inactive.

Following configuring the inductive charging system **30** based on operation mode **0** or **1**, the controller **40** proceeds to step **226** to charge the portable device **25** at full LF band and to provide visual notification to the user of the percent charge completed of the chargeable device **25**. The visual indication may be disposed upon the charging region **24** and/or elsewhere in the charging system **30** or the vehicle. The controller **40** next advances to step **228** to determine whether the 911 Assist call has been initiated. If the 911 Hands-Free Cellular Assist feature has been initiated, then the controller **40** loops back to step **212** in which charging becomes suspended unless the State of Charge (SOC) of the phone falls below X %. The controller **40** then proceeds to step **210** in order to keep suspension of the charge active while the 911 Assist Call is in progress. As noted above, while suspending charging lowers the potential for frequency interference between the charging device **25** and the in-progress or to be initiated 911 Assist, suspension of charging should not be activated when the device **25** may not have sufficient power to fully complete the 911 Assist operations.

If, in step **228**, the controller **40** determines the 911 Assist Call has not been initiated, the controller **40** advances to step **230** to determine if the AM radio is activated at tuner frequencies greater than or equal to a predetermined P kHz. For example, P may be a threshold frequency of 825 kHz. With reference to FIG. 6, if the AM radio is activated, it may send a message to the controller **40** communicating that a particular band is active at a particular frequency range either greater than or equal to a predetermined P kHz or less than a predetermined P kHz. Alternatively, the operating frequency of the AM receiver **56** may be measured by a vehicle access and start controller **54** and the vehicle access and start controller **54** may broadcast a message over the vehicle bus **50** to the charging system **30** indicating the AM radio is operating at a frequency that is interfering with the operating frequency of the inductive charger **30**. If the AM band is detected as active by the controller **40**, the controller **40** proceeds to step **232** and adjusts the operating frequency of the charging system **30** depending on vehicle operating modes labeled **2** and **3** and the type of inductive protocol determined in steps **220** and **252**. As shown in one embodiment in FIG. 6, for example, if AM radio is operating at a tuner frequency less than P kHz, this information is reported to the controller **40**, and if it is determined that the device **25** responds to a second protocol, the controller **40** will provide instructions to shift down the operating frequency by a factor of four (column 2, row 3) when delivering power to the charging coil **27** of the charger **26**. The controller **40** then advances back to step **228** to determine if the 911 Assist Call has been initiated and continues to loop between steps **228**, **230**, and **232** as long as the AM band is detected as active. In addition, if the charging system **30** receives a broadcast message from the bus **50** indicating the radio is in non-AM mode, such as MP3 mode or FM mode, then the charging

system **30** would charge at full LF band without restriction and the controller **40** would proceed to step **234**.

As noted above, if the AM band is inactive at particular tuner frequencies, the controller **40** proceeds to step **234** to determine if a vehicle access and start system query has been initiated. The vehicle access and start system may provide a plurality of automated functions within the vehicle **10** depending on user input, including, but not limited to, allowing drivers to unlock a vehicle by touching a door handle and/or to start the vehicle. The vehicle access and start system may include signal receivers and antennas for processing user input and granting user access. The vehicle access and start system may be controlled by a separate module such as the vehicle access and start controller **54** located within the vehicle **10**. Interactions between vehicle access and start controller **54** and a driver held key fob may occur at a frequency band that may conflict with the operating frequency of the charging system **30**. For example, the vehicle access and start system may communicate with the key fob at a frequency of 125 kHz (Amplitude Shift Key data pulses) and the fob may communicate with the vehicle access and start system at 315 MHz or 901 MHz. If the fob is placed too close to the system **30**, the key fob may sense a vehicle 125 kHz signal due to the 125 kHz energy emitted from the system **30** during charging. In addition, the vehicle access and start system may not begin communication with the key fob unless a particular START, ENTRY or STATUS CHECK condition has been sensed by the system such as the activation of a door handle switch, pushing of a start button, releasing of a brake, or opening of a door.

In step **234**, when the vehicle access and start system has been initiated, the vehicle access and start controller **54** may broadcast a message over the bus **50** to the controller **40** indicating the vehicle access and start system initiation, and the controller **40** will proceed to step **236**. As shown in FIG. 6, if, in step **236**, the controller **40** receives a message indicating the vehicle access and start controller **54** is attempting, for a first time, to communicate with a user held key fob, the controller **40** may hold the LF band setting, but reduce the amount of power used to charge the portable device **25**, for a predetermined amount of time. Such a power reduction may occur while the system **30** is operating in a first inductive protocol or a second inductive protocol, but operating in a third inductive protocol may allow the system to charge the device **25** without restriction, as shown in FIG. 6. If, in step **236**, the controller **40** receives a message indicating the vehicle access and start controller is attempting, for a second time, to communicate with a driver held key fob, the controller **40** may hold the LF band setting but suspend charging of the device completely for a predetermined amount of time (vehicle operation mode **8** in FIG. 6).

In another embodiment, if the controller **40** receives a message indicating the vehicle access and start controller **54** is attempting, for a first time, to communicate with a user held key fob, the controller **40** may exclude a particular frequency band from charging the device **25** (vehicle operation mode **4** in FIG. 6). For example, if the key fob communicates to the vehicle controller **54** at 125 kHz, then the vehicle controller **54** will broadcast an indication of this fact via a data packet to the controller **40** of the inductive charging system **30**. The controller **40** may then operate to delete the frequency band around 125 kHz (115-135 kHz band), thereby allowing the charging system **30** to operate on a non-impaired frequency band. Following reduction or suspension of the inductive charging power (steps **238** or **240**), or adjustment of the frequency of the charging system

11

30, depending on vehicle operating modes 2 and 3 (step 232), the controller 40 loops back to step 228 to determine if a 911 Assist Call has been initiated and continues to loop between steps 228, 230, and 232 as long as the AM band is detected as active.

In another embodiment, an operation for excluding a particular frequency band may depend on the location of the key fob relative to the vehicle access and start system (vehicle operation mode 5, FIG. 6). For example, after vehicle access and start system has been initiated in step 234, it may triangulate the positional coordinates of the key fob to determine if the key fob is a predetermined distance away from the device 25 that is being charged by the system 30. If the key fob is determined to not be within a distance from the device 25, such that there lacks the risk of interfering with the operation of vehicle access and start system, then the charging system 30 can continue to operate on its full LF band. If the key fob is determined to be within a distance from the device 25, such that there would be a risk of interfering with the operation of the vehicle access and start system, then the controller 40 may continue to exclude the particular frequency band from charging the device 25 (vehicle operation 5, FIG. 6).

Either reducing/suspending the amount of power charging of the device 25, or removing the particular frequency band that the system 30 is operating in, will facilitate in reducing the risk that the communicating frequency between the key fob and vehicle controller 40 will be obstructed by the noise caused from inductively charging the device 25. However, removing the band or decreasing the power may also reduce the efficiency of the inductive charging of the device 25. Therefore, if, in step 234, a vehicle access and start system query has not been detected as initiated, the frequency band will not be removed, and the controller 40 will proceed to step 242.

The controller 40 next determines in step 242 whether the chargeable device 25 has been misaligned on the charging system 30. Misalignment may be detected when the device 25 slides out of place to a position that results in the transmitter and receiver coils being offset by up to as much as 12 mm without a charging session termination because of a lack of detected communication between the transmitter and receiver. Misalignment may occur because the chargeable device 25 slides off of an optimal charging position while the vehicle is in motion. Depending on the shape of the phone and the amount of offset, misalignment may result in higher EMF energy radiating from the charging system 30 during charging because of less optimal blocking of such EMF energy from the phone receiver assembly (i.e. receiver coil and ferrite plate). Higher EMF energy radiating from the system 30 may increase the potential for interference with other systems. Thus, when the controller 40 detects the device 25 is misaligned, the controller 40 proceeds to step 244 to hold the LF band setting, but reduces the amount of power charged to the device 25 by a predetermined percentage (operation mode 6, FIG. 6). Reducing the amount of charge will reduce the amount of EMF energy radiating from the charging system 30. The controller 40 then loops back to step 228 to determine if 911 Assist Call has been initiated.

If the controller 40 determines the device 25 is not misaligned, then it proceeds to step 246 to visually indicate an update of the charging status to the user. Such visual indication may show a new percentage charge completed for the device 25. The controller 40 then proceeds to step 248 to determine if the charging of the device 25 has been completed. If not, then the controller 40 loops back to step 246 to determine the charging status of the display. When

12

charging of the device 25 has been completed, the controller 40 proceeds to step 250 to visually indicate to the user that the charging event has been completed and then proceeds to the end process.

Referring now to FIG. 8, a method 300 is shown that may be executed by the controller 40 and is generally used when the receiver 56 of the radio is operating in the AM band and the charger 30 is charging the chargeable device 25. Operating the receiver 56 in the AM band may present a number of challenges while the charger 30 is operating. Integer multiples, or harmonics, of the charging band frequency of the charger 30 may form interference onto which the receiver 56 will lock. For example, if the fundamental charging frequency of the charger 30 is 110 kHz, the charging will emit harmonics of decreasing amplitude in integer multiples of 110 kHz such as 220 kHz, 330 kHz, 440 kHz, 550 kHz, etc. These integer multiples may extend and radiate through the AM band, causing the receiver 56 to lock on them and prevent the driver or other user in the vehicle 10 from efficiently scanning the AM band.

Method 300 begins with step 304 of detecting activation of the AM band when the charger 30 is active. The AM band may be activated via a physical button, switch, knob, a virtual button on a human-machine-interface or the like, voice command, as part of another sequence of events, or other method of activation. The AM band may be activated in a plurality of modes, including a scanning mode and a tuning mode. In the scanning mode, the driver or user initiates the AM band scanning mode and the AM/FM receiver 56 begins automatically scanning through AM frequencies (e.g., in an increasing or decreasing progression) from a start point (e.g., a predetermined AM frequency or the last used frequency) and stops or settles (e.g., either briefly or permanently) on a frequency which has a signal. In the tuning mode, the driver or user may manually advance through the frequencies or the AM band and settle on a desired frequency. Once the receiver 56 is activated in the AM band, the receiver 56 sends a signal to the controller 40 indicating activation of the AM band. It will be understood that although method 300 is explained as being initiated when the AM band is activated during charging of the chargeable device 25, method 300 may also be initiated by charging of the chargeable device 25 while the receiver 56 is already active in the AM band.

Once the controller 40 detects the activation of the AM band, step 308 of adjusting the charging band frequency and/or power of the charger 30 is performed. In various embodiments, immediately after the controller 40 senses the selection of the scanning mode or the tuning mode in the AM band, the charging band frequency of the charger 30 is shifted (e.g., up or down in frequency) by a predetermined amount (e.g., 2.5 kHz), as explained above. In other embodiments, the shift in charging band frequency of the charger 30 may be delayed. Additionally or alternatively to a frequency shift of the charging band frequency, the charger 30 may reduce the charging power it supplies to the chargeable device 25 upon indication that the AM band is activated. The power transferred from the charger 30 to the chargeable device 25 may be completely eliminated (i.e. no charging) or reduced to about the minimum power needed to maintain charging of the chargeable device 25 as explained above.

In some embodiments of the tuning mode, prior to shifting of the charging band, frequency of the charger 30 is delayed to determine if the tuning frequencies are in a predetermined portion of the AM band. The predetermined portion of the AM band may cover a range of AM band frequencies in which integer multiples of the charging band frequency are

13

likely to be present and cause interference with the receiver 56. Exemplary ranges for the predetermined portion of the AM band range from about 100 kHz to about 1500 kHz, from about 200 kHz to about 1000 kHz, and from about 540 kHz to about 900 kHz. If the sensed tuning frequencies of the tuning mode fall within the predetermined portion of the AM band, the controller may then immediately shift the charging band frequency of the charger 30 as explained above. In various embodiments, if the tuning frequencies are on a threshold (e.g., with about 100 kHz of the upper or lower frequencies of the predetermined portion) or outside of the predetermined portion, the charger 30 may maintain the standard or normal charging band frequency and power.

Next, in step 312, the controller 40 determines whether or not the receiver 56 has settled on a frequency. In various embodiments, the controller 40 may determine that the receiver 56 has settled on a frequency when the receiver 56 has been tuned to that frequency for a predetermined amount of time. For example, the predetermined amount of time may be between about 0.11 second and about 25 seconds, between about 1 second and about 20 seconds, and in a specific embodiment about 15 seconds.

Next in step 316, once the controller 40 has determined that the receiver 56 is settled on a frequency, the controller 40 determines if the frequency chosen is an integer multiple of the charging band frequency. If the settled on frequency by the receiver 56 is an integer multiple of the charging band frequency of the charger 30, the controller 40 may keep the charger 30 at the adjusted frequency and/or power level.

If the controller 40 determines that the settled on frequency is not an integer multiple of the charging band frequency, the controller 40 transitions to step 320. In step 320, the controller 40 adjusts the charging band frequency and/or power back to the normal or optimal charging conditions for the charger 30 and chargeable device 25. In some embodiments, based on the settled on frequency of the receiver 56, the charging frequency and/or power of the charger 30 may not be shifted back to the optimal configuration, but may be altered.

Accordingly, the wireless inductive charging system 30 advantageously reduces or prohibits emission of energy from radiating at certain charging frequencies or operating at certain power levels within a charging region. This advantageously prevents the electromagnetic field created by the charger during wireless charging from interfering with the operation of other devices or systems in its proximity. The wireless charging system 30 is particularly well suited for use on a vehicle where there are many electronic devices that may operate on a similar frequency band as the wireless system. However, the system may be useful for other applications. It should be appreciated that when the object is no longer detected as interfering with other devices, the wireless charging may be increased and resumed.

It is to be understood that variations and modifications can be made on the aforementioned structure without departing from the concepts of the present invention, and further, it is to be understood that such concepts are intended to be covered by the following claims unless these claims by their language expressly state otherwise.

What is claimed is:

1. A method for reducing interference in an inductive charging system, the method comprising:
inductively charging a chargeable device with an inductive charger;
detecting the operation of a receiver in an AM band; and
adjusting at least one of a frequency band employed by the charger, and an amount of power provided to the

14

chargeable device by the charger, based on the operation of the receiver in the AM band.

2. The method of claim 1, wherein the receiver has at least one of a scan mode or a tunable mode of operation in the AM band.

3. The method of claim 1, further comprising the step of detecting the receiver settling on a frequency in the AM band for more than a predetermined amount of time.

4. The method of claim 3, further comprising the step of determining if the settled on frequency is an integer multiple of the frequency band at which the inductive charger charges the chargeable device.

5. The method of claim 4, further comprising the step of adjusting at least one of the frequency bands employed by the charger, and the amount of power provided to the chargeable device by the charger, if the settled on frequency is not an integer multiple of the frequency band at which the inductive charger charges the chargeable device.

6. The method of claim 5, wherein the adjustment of at least one of the frequency bands employed by the charger, and the amount of power provided to the chargeable device by the charger, is adjusted back to a normal operating frequency and a normal operating power if the settled on frequency is not an integer multiple of the frequency band of operation of the charger.

7. The method of claim 1, wherein the adjustment of the amount of power provided to the chargeable device by the charger lowers the amount of power provided to about a minimum power needed to maintain charging of the chargeable device.

8. A charging system for reducing interference during inductive charging of a chargeable device, comprising:

an inductively powered charger; and

a controller configured to detect the selection of an AM tuning mode of a receiver in proximity to the charger and adjust a frequency band employed by the charger if the receiver is tuned to a frequency within a predetermined portion of the AM band.

9. The charging system of claim 8, wherein the controller adjusts an amount of power provided to the chargeable device by the charger.

10. The charging system of claim 9, wherein the adjustment of the amount of power provided to the chargeable device by the charger is to about a minimum power needed to maintain charging of the chargeable device.

11. The charging system of claim 8, wherein the predetermined portion of the AM band extends from about 200 kHz to about 1000 kHz.

12. The charging system of claim 11, wherein the predetermined portion of the AM band extends from about 540 kHz to about 900 kHz.

13. The charging system of claim 8, wherein the controller detects the receiver settling on a frequency in the predetermined portion of the AM band for more than a predetermined amount of time.

14. The charging system of claim 13, wherein the controller is configured to determine if the settled on frequency is an integer multiple of the frequency band at which the charger charges the chargeable device.

15. An in-vehicle system for reducing interference during inductive charging of a chargeable device, comprising:
a charger region provided in a vehicle;
an inductively powered charger; and
a controller in communication with the inductive charger, wherein the controller detects operation of a vehicle

15

receiver in a scan mode of an AM frequency band in proximity to the charger and adjusts a frequency band employed by the charger.

16. The system of claim **15**, wherein the controller adjusts an amount of power provided to the chargeable device by the charger to about a minimum power needed to maintain charging of the chargeable device. 5

17. The system of claim **15**, wherein the controller detects the receiver settling on a frequency in the predetermined portion of the AM band for more than a predetermined amount of time. 10

18. The system of claim **17**, wherein the controller is configured to determine if the settled on frequency is an integer multiple of the frequency band at which the charger charges the chargeable device. 15

19. The system of claim **18**, wherein the controller is configured to adjust the frequency band employed by the charger, and the amount of power provided to the chargeable device by the charger, if the settled on frequency is not an integer multiple of the frequency band at which the inductive charger charges the chargeable device. 20

20. The system of claim **15**, wherein the charger inductively charges the chargeable device at a charging frequency having harmonics in the AM frequency band.

* * * * *

25

16